

Product Brochure

Pulsed Field Magnetometer (PFM) 8th generation – PFM08 revision 2

The PFM08 range of magnet characterisation magnetometer can rapidly and accurately measure the magnetic hysteresis loop and extract key values for all high-grade permanent magnetic materials such as NdFeB, SmCo, Ferrite and all coated magnets. With a maximum field of 10.5T (8356 kA/m / 105 kOe) even the most coercive materials and highest grades of NdFeB or SmCo can be measured, while traditional permeameters cannot measure these high coercivity materials due to pole piece saturation limitations. The 8th generation of PFMs from Hirst uniquely feature the eddy current correction (patented F-2F algorithm), Self-Demagnetisation Field (SDF) correction function (to allow accurate measurement of a wide range of samples from cylinders, cuboids and arbitrary sample shapes), and Hirst proprietary Self De-magnetisation Field Function SDFF™ (patented) which accurately generates an open to closed circuit mapping (O2C™). The first generation of Hirst industrial PFM was launched in 1998 and the company won an Institute of Physics business award for the SDFF™ technology in 2020. Thus generation 8 PFMs give permeameter-like measurements for the highest grades of magnets to within 1% on permeameter reference measurements. HirstLab v2.0 software and Hirst proprietary SDFF™ technology has been implemented in collaboration with the National Institute of Metrology (NIM), Beijing, as part of a contract for the first 8th generation PFM placed by NIM.



PFM08-10 AT / HT



PFM08-40 HT



PFM08-40 MT (-40 °C to +220 °C)

Key benefits

- All high-grade permanent magnets can be fully characterised such as NdFeB (inc AH), SmCo, hard Ferrites and coated magnets
- Full 4 quadrant measurement of magnetic hysteresis loops
- The PFM contains an integral capacitive discharge magnetiser (and demagnetiser) producing a field of over 10T meaning the highest grades of permanent magnetic material can be tested (which is not possible on traditional permeameters) thus can test samples that are magnetised or unmagnetised
- User friendly HirstLab v2.0 software for fast precise measurements
 - HirstLab v2.0 software automatically extracts critical parameters: Remanence: B_r , Coercivity: H_{cj} , H_{cB} , Maximum energy product: BH_{Max} , Saturation values: H_{sat} , J_{sat} , Squareness Coefficients: H_k , H_k/H_{cj} , H_d (H_{d2} , H_{d5} , H_{d10}) and S_a are all automatically extracted from every measurement and displayed separately alongside JH and BH loops.
 - Any shape : cylinders, cuboid, and arbitrary shapes with built-in Self-Demagnetisation Field (SDF) shape correction function.
 - Unique Self Demagnetisation Field Function SDFF™ in HirstLab v2.0 which accurately generates an open-to-closed circuit mapping (O2C™) for the magnet sample giving accurate closed loop magnet parameters. Generation 8 PFMs give permeameter-like measurements for the highest grades of magnets
- The PFM08 revision 2 hardware platform features the lowest measurement noise achieved to date on Hirst PFMs and interchangeable pick-up coil sets to offer the highest sensitivity for specific sample sizes this allows a range of

- sample sizes to be repeatably tested from 1x1x1 mm to 70mm
- Precision sample temperature measurement with integral high precision sample temperature control:
 - Stabilised ambient temperature measurements on all models from 17°C to 28 °C
 - High temperatures up to +220°C on HT models
 - Low temperatures down to -40°C for the PFM08-40 MT
- Temperature control precision better than $\pm 0.2^\circ\text{C}$ for ambient measurements
- Repeatability better than $\pm 0.2\%$ at ambient temperature for H_c and B_r on standard samples
- Meets IEC (International Electrotechnical Commission) TR-62331 specifications for permanent magnets which is a non-destructive testing method.

Applications

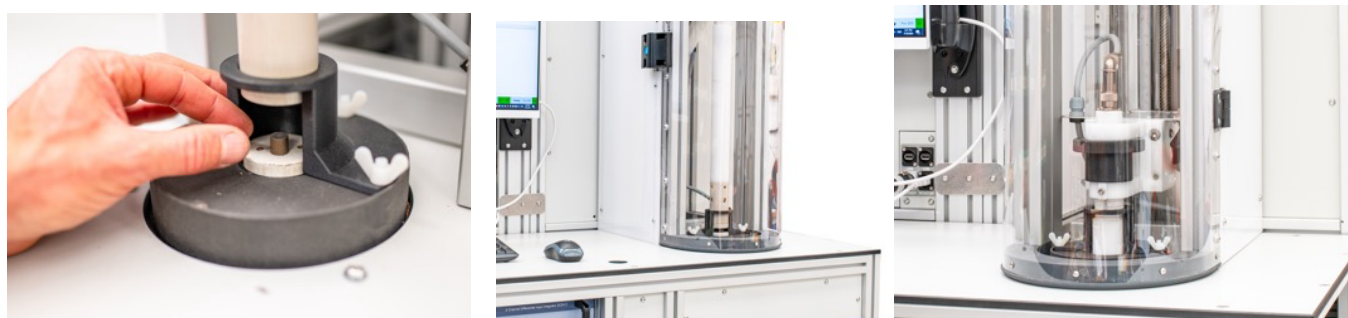
- Designed for characterisation of hard magnetic materials in both production control and research applications. for all permanent magnet materials (Ferrite, NdFeB, SmCo, AlNiCo) including high grade NdFeB coated samples
- These PFMs are ideal for high-speed production testing and quality control with users being able to achieve test times of less than a minute
- The optional small sample kits available on PFM08-10 and PFM08-40 to test samples down to 1x1x1mm for grain boundary diffusion (GBD) magnets testing
- Thin sample mode for accurate measurement of 1mm thick slices on PFM08-10 and PFM8-40 often used for GBD magnet development and testing
- The large sample PFM08-40 HT support quality control applications in EV manufacture with samples sizes up to 40mm and the PFM08-70 HT for samples up to 70mm diameter
- Some high temperature versions support measurement up to 220°C for development and quality control.
- Low temperature versions support measurements down to -40°C for materials research

Hirst Pulsed-Field Magnetometry systems

Designed for industrial use, the PFM offers fast, accurate, full hysteresis loop measurements of all industrial magnets, with unparalleled speed and repeatability. Full 4 quadrant loops can be generated in less than 1s and PFMs are a non-destructive testing and characterisation. The process needs no pre-magnetisation of magnets (unlike permeameters) and can deliver a magnetised or demagnetised magnet at the end of the cycle.



Above: PFM08-10 AT sample holder stick, a PFM08-10 AT in operation. Samples stick storage on the side of the PFM08-10 and sample temperature measurement displays.



Above: PFM08-40 MT in operation showing loading the sample (left) into the automated sample management system (centre) which then manages the sample location, heating cooling and measurement automatically (right sample in measurement position).

High Speed Measurement

The measurement pulses on PFM08s are a fraction of a second for a full 4 quadrant measurement with most of the rest of the test cycle time spent on sample loading and temperature stabilisation of the sample. The system offers repeatability of measurements at speeds that are simply unattainable with other methods of measurement. The measurement process involves generating large pulsed magnetic fields. These pulsed magnetic fields drive the magnet around its major hysteresis loop. Suitably placed pickup coils detect the applied field and the magnets response to the applied field. J and H signals are fed to the PC where they are processed to form JH and BH loops representing the characteristics of the magnetic material.

The PFM then automatically proceeds to measure the full loop characteristics and displays the results immediately with all critical parameters automatically extracted.

Even in high precision metrology tests of a standard 10mm diameter block test sample a fully temperature stabilised measurement will only take 5 minutes and if temperature correction is used for rapid ambient testing, a test will take less than 1 minute including sample loading on the PFM08-10. In magnet block testing applications for quality control users regularly test >60 samples per hour on the PFM08-10, some even more. The PFM08-40 offers similar test speeds but with the measurement steps fully automated.

Automation

With the PFM08-40 once the sample is placed in the sample loading area and the safety door is closed the PFM08-40 automatically manages the sample, moving to the heating or cooling zones for temperature stabilisation and into the optimum location for magnetisation, measurement or demagnetisation all controlled and monitored via HirstLab v2 running on the embed industrial PC with no user intervention is required. Once the required tests are performed the sample is returned to the loading area.

The PFM08-40 also further automates the measurement process via a powerful built-in scripting tool that allows full automation of standard tests such as temperature sweeps say at 20 °C intervals over a wide range of temperatures – often used to generate datasheets. The PFM08-40 automatically runs the test procedures and stores the data so there is no more standing around waiting for instructions from the machine and moving samples about to different positions in the machine as required

The PFM08-40 platform is designed to allow further automation of testing to reduce labour costs and opens the possibility of rapid 100% testing of magnetic parts as required.

Temperature control and monitoring

The PFM08 range have integral sample temperature control and monitoring and features two methods for dealing with sample temperature: stabilised temperature and temperature corrected. In the stabilised temperature mode, the sample's temperature is directly controlled & stabilised, and measurements are taken at the specific desired sample temperature. Temperature corrected measurements are quicker as the sample is measured at its current temperature and the values obtained are corrected to the desired ambient temperature point – this is often used in quality control applications where quicker measurements are required and data needs to be compared at specific ambient temperature.

Any Shape

The PFM can measure any shape of magnet and as standard cylinders, cuboids are included in HirstLab v2 with a look up table with the built in Self-Demagnetisation Field (SDF) shape correction function. For more complex and arbitrary shapes this can be calculated with FEM although HirstLab v2 app by simply loading the shape into the app and copying over the SDF value.

Unique SDF technology

In addition, HirstLab v2 has a unique Self Demagnetisation Field Function SDF™ which accurately generates an open-to-closed circuit mapping (O2C™) for the magnet sample generating accurate closed loop magnet parameters as a

permeameter would. Thus generation 8 PFM's give permeameter-like measurements for the highest grades of magnets to within 1% on permeameter reference measurements from NIM.

Small Sample kits

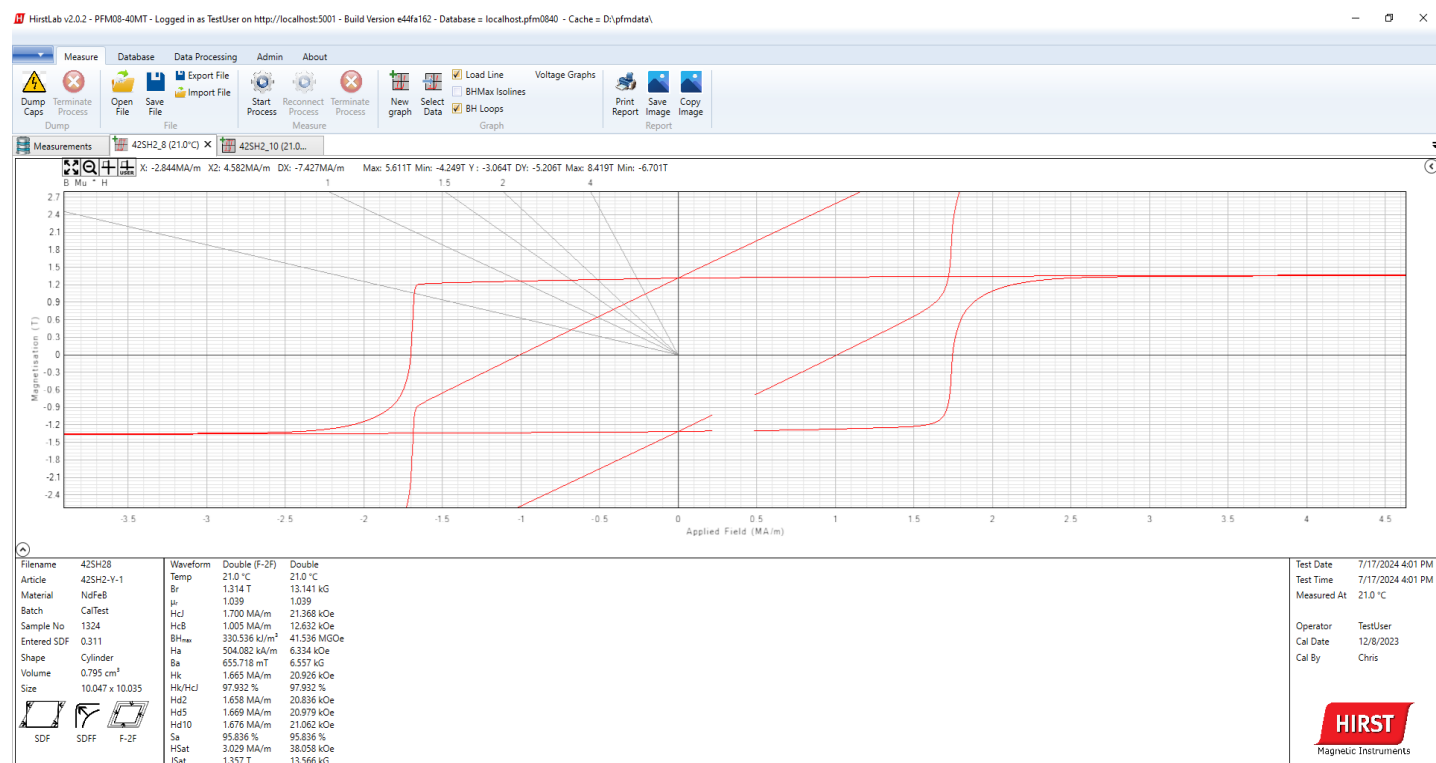
One of the major improvements in the revision 2 hardware platform for the generation 8 PFM's is that it allows user interchangeable pick-up coils of different diameters and sensitivities for optimum measurements of samples of differing sizes. In addition, the measurement noise levels have been dramatically reduced compared to previous generations of Hirst PFM's. The combination allows the highest level of measurement repeatability over a wide range of sample sizes. For example, on the PFM08-10 with the optional small sample (SHS-05-PT kit) can achieve a full sample reload repeatability on coercivity (H_c) of $\pm 0.5\%$ for a reference 1x1x1mm sample – which is a remarkable result considering the small sample volume. A small sample kit is also available on the PFM08-40 but with automated measurement capability.

HirstLab v2 – Powerful and easy to use software

All new Hirst PFM systems are supplied with comprehensive software, HirstLab v2.0. The HirstLab v2.0 software combines all of Hirst's expertise and PFM technology into a single, easy-to-use package. The software manages the operation of the machine and maintains a database with the history of all measurements. A flexible plotting tool provides multiple views of the measured data.

Automatically extracts critical measurement parameters

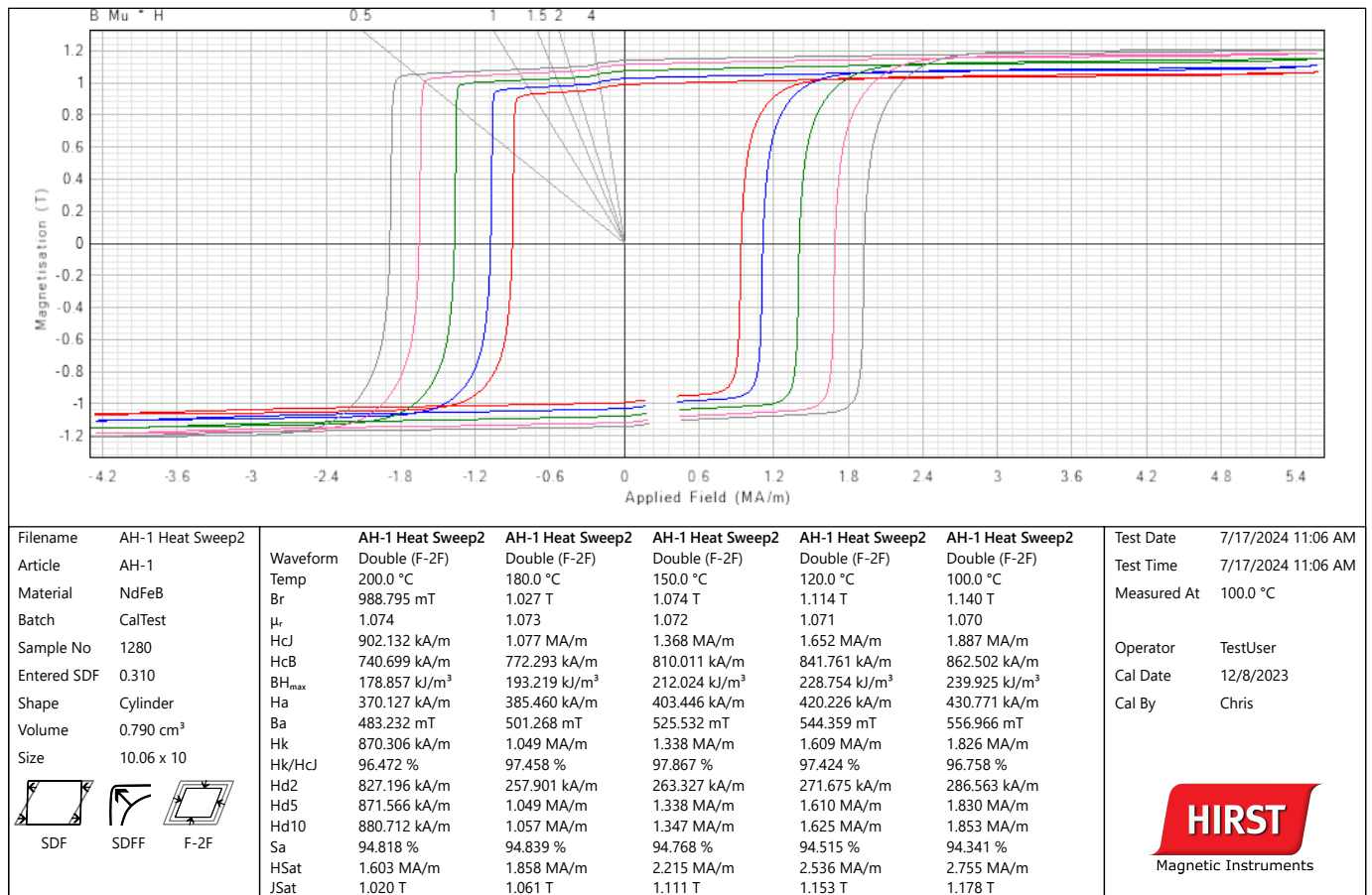
Remanence: B_r , Coercivity: H_{cJ} , H_{cB} , Maximum energy product: BH_{Max} , Saturation values: H_{sat} , J_{sat} , Squareness Coefficients: H_{kr} , H_k/H_{cJ} , H_d (H_{d2} , H_{d5} , H_{d10}) and S_a are all automatically extracted from every measurement and displayed separately alongside JH and BH loops shown below



The graph below was generated on the PFM08-40 and shows a temperature sweep from 100 °C to 200 °C at 20 °C intervals. This was done using the powerful built-in scripting tool, the sample was loaded and then all measurements were automatically taken and stored in the measurement database with no further user intervention required. Once the sample was loaded and the automation script started all the measurements were completed in about 30 minutes the sample was returned demagnetized to the sample loading position ready for the next task.

Pulsed Field Magnetometer Report

Hirst Magnetic Instruments Ltd



Full graphical display

The software can simultaneously display multiple loops in either one or multiple windows for easy comparisons. A comparison function is available for the demagnetisation quadrant to highlight any differences between measurements. Data is also available as a hard copy via a printer and can be displayed with a choice of S.I. and/or c.g.s. Units and a fully customisable report format.

All the PFM's functions are accessible through the user interface including the extensive data processing and storage features. The software follows similar design to many other applications that run on Microsoft Windows™ creating a familiar environment and reducing the time to learn the software.

Measurement database for 100% traceability

A measurement database stores every measurement made on the system ensuring 100% traceability and making it impossible to lose a measurement. A more traditional system of entering filenames is also available but it is not a requirement to use it. Especially useful for industrial quality assurance (QA) and similar applications. The database can be stored on the built in PC or on a central server so that multiple PFM machines can be monitored from a central location. The database supports filtering through a range of parameters such as operator name, sample data etc, which allows easy recollection of any previous data.

Along with a measurement database HirstLab v2.0 also provides a sample database. Details of sample properties, dimensions, and required measurement parameters can be stored. When a measurement of that sample is taken the measurement settings are automatically set-up based on the parameters stored in the sample database. The sample details are also used in the processing of data to produce JH and BH loops that are calibrated to unit volume.

The screenshot shows the HirstLab software interface. On the left, there are buttons for 'Get Articles', 'Add Article', 'Update Article', and 'Delete Article'. Below these is a form for adding or updating an article with fields for Article name, Material, Description, Shape, Height, Diameter, Volume, Soak Time, and Self Demag Factor. On the right, there is a table listing articles with columns for Article Name, Material, Description, Shape, Dim A, Dim B, Dim C, and Volume. The table shows various articles like 44H-1, 45M-1, 45SH, etc., with their respective materials and dimensions.

Report generation

HirstLab v2.0 can produce a detailed report describing the characteristics of the measured sample or a summary report from a set of measurements. There are several easy to use and powerful report formats built here is one example showing a sample re-load test at ambient

Batch	Filename	Article	Operator	Date	Time	Description	Temperature	Br	HcJ	HcB	BHMax	HkHcJ
reload	42SH2-Y I	42SH2-Y	Jack	2/14/2024	6:08:36 PM		20.4°C	1.320 T	1.698 MA/m	1.017 MA/m	336.292 kJ/m ³	93.521 %
reload	42SH2-Y II	42SH2-Y	Jack	2/14/2024	6:12:32 PM		20.4°C	1.321 T	1.698 MA/m	1.016 MA/m	336.440 kJ/m ³	93.484 %
reload	42SH2-Y III	42SH2-Y	Jack	2/14/2024	6:18:06 PM		20.4°C	1.321 T	1.699 MA/m	1.016 MA/m	336.384 kJ/m ³	93.484 %
reload	42SH2-Y IV	42SH2-Y	Jack	2/14/2024	6:22:54 PM		20.4°C	1.321 T	1.698 MA/m	1.017 MA/m	336.682 kJ/m ³	93.524 %
reload	42SH2-Y V	42SH2-Y	Jack	2/14/2024	6:28:59 PM		20.4°C	1.322 T	1.701 MA/m	1.017 MA/m	337.010 kJ/m ³	93.525 %
reload	42SH2-Y V	42SH2-Y	Jack	2/14/2024	6:33:36 PM		20.4°C	1.321 T	1.697 MA/m	1.017 MA/m	336.542 kJ/m ³	93.536 %
reload	42SH2-Y VI	42SH2-Y	Jack	2/14/2024	6:39:34 PM		20.4°C	1.322 T	1.700 MA/m	1.018 MA/m	337.159 kJ/m ³	93.510 %
reload	42SH2-Y VII	42SH2-Y	Jack	2/14/2024	6:44:01 PM		20.4°C	1.322 T	1.700 MA/m	1.018 MA/m	336.908 kJ/m ³	93.499 %
reload	42SH2-Y VIII	42SH2-Y	Jack	2/14/2024	6:48:32 PM		20.4°C	1.322 T	1.701 MA/m	1.017 MA/m	336.878 kJ/m ³	93.490 %
reload	42SH2-Y IX	42SH2-Y	Jack	2/14/2024	6:53:52 PM		20.4°C	1.322 T	1.700 MA/m	1.018 MA/m	337.015 kJ/m ³	93.500 %
Mean								1.321 T	1.699 MA/m	1.017 MA/m	336.731 kJ/m ³	93.507 %
Max								1.322 T	1.701 MA/m	1.018 MA/m	337.159 kJ/m ³	93.536 %
Min								1.320 T	1.697 MA/m	1.016 MA/m	336.292 kJ/m ³	93.484 %
Peak error +/- %								0.063 %	0.138 %	0.098 %	0.129 %	0.028 %
Standard deviation								0.042 %	0.079 %	0.057 %	0.086 %	0.019 %

Data export facilities

Comprehensive data export facilities allow data to be easily migrated to other software applications including exporting to .csv, .JSON, .nc formats.

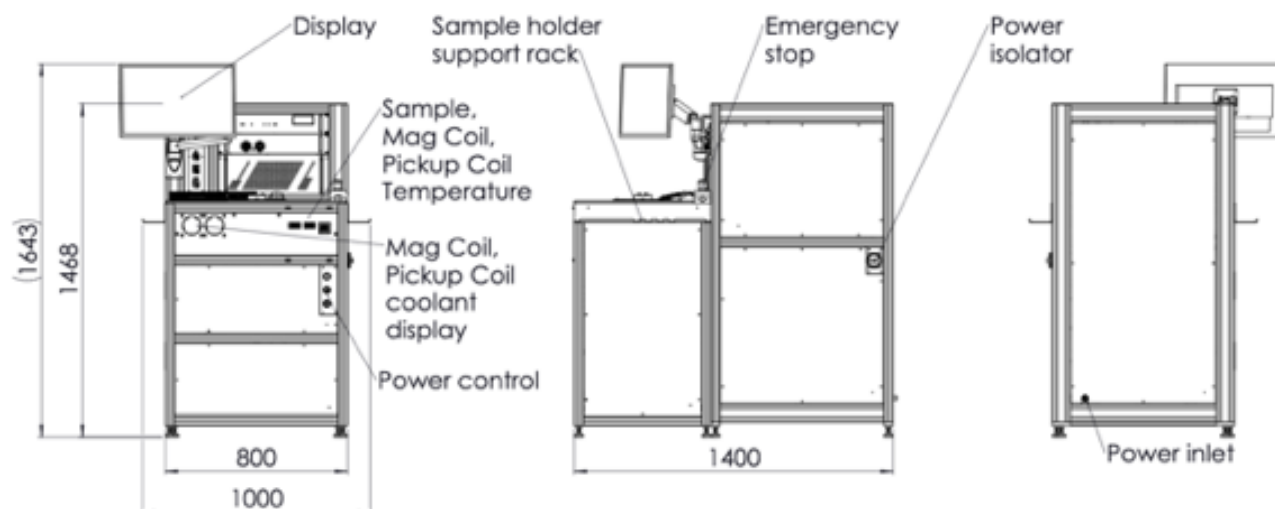
Range overview

Product Number	Sample size	Sample Management	Typical Application
PFM08-10 AT +20 MH	5-10mm diameter, 1-20mm height	Manual	Magnet supply chain with thin sample mode for GBD with optional small sample kit samples down to 1x1x1mm (ambient testing)
PFM08-10 HT +20+200 MH	5-10mm diameter, 1-20mm height	Manual	Magnet supply chain with thin sample mode for GBD with optional small sample kit for samples down to 1x1x1mm (ambient testing)
PFM08-40 HT+20+220 AH	5-40mm diameter, 1-30mm height	Automatic	Modular PFM with large sample range and automated sample handling for use in magnet supply chain with thin sample mode and optional small sample kit for samples down to 1x1x1mm - also ideal for magnet user
PFM08-40 MT -40+220 AH	5-40mm diameter, 1-30mm height	Automatic	National labs and materials research for extended temperature range with thin sample mode small sample kits for 1x1x1mm samples
PFM08-70 HT +20 +220AH	5-70mm diameter, 5-20mm height	Automatic	Magnet supply chain and magnet user quality control

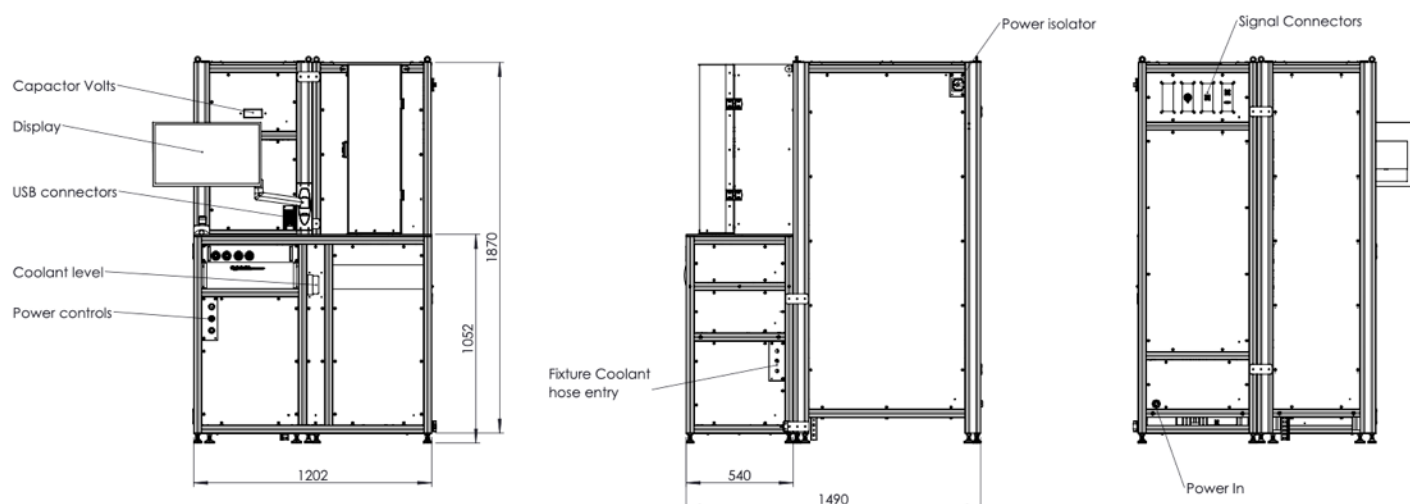
Technical data

Magnetisation pulse	Full period sine wave
Magnetiser Energy, Voltage and Peak field	PFM08-10: 9kJ, 3000V, 10T peak (7958kA/m / 100k Oe) PFM08-40 and 08-70: 45kJ, 3000V, 10.5T peak (8356 kA/m / 105k Oe)
Eddy current removal	Compensation for linear and non-linear rate dependant effects via Hirst proprietary F-2F algorithm
Field correction	Built in Self-Demagnetisation Field (SDF) shape correction function
Permeameter equivalent curve	Hirst proprietary Self De-magnetisation Field Function SDFF™ which accurately generates an open to closed circuit mapping (O2C™) for the magnet sample giving accurate closed loop magnet parameters
Standard Sample sizes	PFM08-10 test area 5-10mm diameter, 1-26mm height (optional small sample kit down to 1x1x1mm on 08-10 HT) PFM08-40 test area 5-40mm diameter, 1-30mm height (optional small sample kit down to 1x1x1mm) PFM08-70 test area 5-70mm diameter, 5-20mm height (upper sample volume limit of 12,000mm ³)
Sample shapes	Any shape via SDF correction – with built in standard shape look up including cylinder and cuboids. A powerful SDF calculator app is included for all other shapes Thin sample mode on 08-10 and 08-40 for testing thin slices (GBD)
Sample temperature stabilisation*	PFM08-10 AT: $\pm 0.5^{\circ}\text{C}$ (sample at ambient) PFM08-10 HT : $\pm 0.2^{\circ}\text{C}$ (sample at ambient) PFM08-40 HT / MT and PFM08-70 HT: $\pm 0.2^{\circ}\text{C}$ (sample at ambient)
Repeatability*	B_r and $H_{cj} \pm 0.2\%$ for 08-10 (ambient measurement, standard samples) B_r and $H_{cj} \pm 0.2\%$ for 08-40 (ambient measurement, standard samples) B_r and $H_{cj} \pm 0.2\%$ for 08-70 (ambient measurement, standard samples)
Display and controls	Windows 11 computer, Intel i5 processor, 1TB storage, intuitive software with simple test initiation controls and full database system, 24" HD colour monitor, wireless keyboard and mouse (supplied)
Colours and materials	Steel and Aluminium case
Dimensions / Weight	PFM08-10: 1000mm x 1400mm x 1468mm / 450kg PFM08-40: 1202mm x 1490mm x 1875mm / 995kg PFM08-70: 1202mm x 1490mm x 1875mm / 995kg
Connectivity	100 Mbps ethernet via RJ45, WIFI and USB
Recommended Machine Operating Range	+18 °C to +23 °C
Power Supply	PFM08-10: Single Phase 220/240VAC 50-60Hz 32A or 110VAC option Max 3m cable length PFM08-40 & PFM08-70: Single Phase 220/240VAC 50-60Hz 32A or 110VAC option Max 3m cable length (and an additional single phase 220/240VAC 50-60Hz 16A or 110VAC option for external chiller power connection is required)

*For specific sample performance data, see detailed specifications for each machine



PFM08-10 AT and HT (above)



PFM08-40 HT/ MT and PFM08-70 HT (above)

Warranty and Calibration

Supplied calibrated with 1 year warranty. A calibration is required every year to maintain the highest levels of performance – Hirst has a dedicated team of installation and service engineers, available to travel worldwide to install and support equipment, service contracts are available. Contact your local distributor for details.

Accessories

Basic reference magnet sample packs:-

- **RM-AT** - Ambient N40H, N42SH samples with NIM certification
- **RM-HT** - contains RM-AT samples plus 100°C and 150 °C samples with NIM certification
- **RM-HT+** - contains RM-HT samples plus 180 °C sample with NIM certification



Hirst Magnetic Instruments has been active in providing solutions for 60 years in magnetics and magnetic measurement. Hirst manufactures precision hand-held gaussmeters, fluxmeters, demagnetisers, bench top & workstation industrial magnetisers, industrial production-line magnetisers, pulsed field magnetometers (PFMs) for characterising magnetic materials.

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PFM08 product range brochure v4.3c 1.8.24